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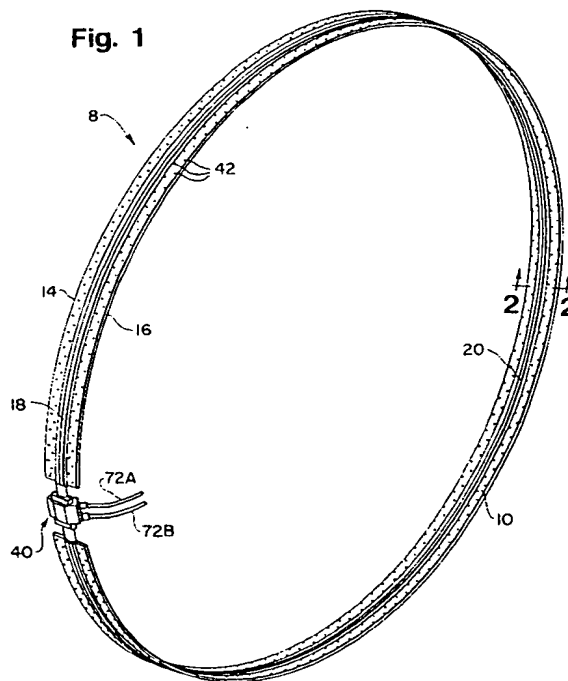
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**D-85354 Freising (DE)**(54) **Frangible annular joint for connecting and disconnecting two elements.**

(57) An improved explosively operated separation joint as well as a process for manufacturing it are disclosed. In the present invention, a hollow-form extrusion is used to provide both sides of a separation joint, each side being attached to both of the two structures. Each end of the joint is attached to a respective one of the two structures. A stainless steel tube is inserted into the hollow portion of the extrusion. The extrusion then is rolled to form a portion of a ring. An explosive core covered by an elastomeric sheath is inserted into the length of the tube. The ends of the ring then are connected to and sealed by an initiation manifold. The manifold provides an interface between each of two flexible confined detonating cords ("FCDCs") with a respective end of the explosive core. The manifold includes a barrier between the ends of the explosive core and the two FCDCs that prevents sympathetic damage to either end of the explosive core and the associated FCDC by the detonation of the other.

**Fig. 1****EP 0 596 400 A2**

## BACKGROUND OF THE INVENTION

The invention relates to an explosive separation system for a variety of applications, and more particularly, to a reliable, clean operating and low cost separation joint made by an extrusion and rolling process. The extrusion process facilitates the manufacture of a single frangible joint member that replaces a pair of rings in prior art separation systems, thereby simplifying manufacture and assembly with the attendant cost savings. Explosive separation systems are most commonly used for stage and payload separation in various space applications.

Existing explosive separation joints are costly to manufacture. The primary sources of these costs are the precision machined rings they employ and the tedious assembly process required. For example, the explosive system disclosed in U.S. Patent No. 3,698,281 requires the manufacture of two separate precision machined rings 50 and 52 (shown in cross section in FIG. 3). After manufacture, the rings 50 and 52 are attached to the two sections to be joined, 54 and 56. One ring 52 is attached to the interior portion of sections 54 and 56, while the other ring 50 is attached to the exterior portion of sections 54 and 56. Each ring 50 and 52 has a recess, which together form a hollow portion 58 to receive an explosive core when the rings are assembled. The placement of the rings 50 and 52 has to be performed with great accuracy to ensure that an explosive core within the hollow portion 58 is properly positioned to completely separate sections 54 and 56 after detonation. Each ring 50 and 52 also has a notch 60 in the side opposite the recess, along which the rings 50 and 52 separate upon detonation of the explosive core. The thickness of the material between each notch 60 and the explosive core 62 must be controlled precisely in order to ensure that the explosion of core 62 will cause complete separation around the entire circumference of rings 50 and 52.

Typically in the prior art, the ends of the tube containing the explosive core are sealed using a "swaging" process in which a round mandrel projecting from a block is pulled inside the tube. This causes the tube to flare to match the mandrel and results in a tight fit between the manifold and the tube. The explosive core extends completely through the mandrel and block via a bore. The block is then attached to the tube by welding. In prior art joints, while the majority of the tube length is oval, the ends are left round to facilitate the foregoing attachment. Thus, the manufacture of the prior art joint required precision machined rings and their meticulous assembly with the explosive core and attachment to the structures to be separated.

By contrast, the present invention employs a single-piece, hollow-form extrusion containing an explosive core, rather than two separate plates or rings (one on the inboard side and one on the outboard side of the explosive core). The process of forming and attaching a single extrusion joint avoids the need for precisely machining and attaching two separate rings, which can be up to several feet in diameter. The joint of the present invention also comprises a new manifold that facilitates sealing the ends of the extrusion and initiating detonation of the explosive core. Thus, the extruded frangible joint of the present invention is superior to prior art joints employed in explosive separation systems.

## OBJECT AND SUMMARY OF THE INVENTION

Thus, an object of the present invention is to provide a superior, reliable, and clean operating explosive separation system that is easier and less expensive to manufacture and assemble than prior art systems. The present invention accomplishes this object by using a single-piece extrusion having a hollow portion (which comprises a tube cavity), a pair of fringing notches, one on either side opposite the hollow portion of the extrusion, and two attach flange portions for joining the two sections to be explosively separated. The two portions of the extrusion comprising the flanges are positioned on either end of the joint with the tube cavity between them. An inner stainless steel tube is inserted into the hollow portion of the extrusion. This tube contains the byproducts of the explosion after detonation, and can be eliminated in applications where avoiding contamination of the surrounding area is not important. The extrusion is then rolled into its final shape -- e.g., an open ring if it is to be used to join two cylindrical portions of a spacecraft. The explosive core, a dual initiated linear explosive comprising a Mild Detonating Fuse (MDF), is placed in a rubber sleeve. Then the explosive core and rubber sleeve are pulled through the stainless steel tube in the hollow portion of the extrusion. Finally, an initiation manifold is attached to the tube ends to close the ring and seal the tube. Prior art mandrels are unsuitable for use with the frangible joint of the present invention, however, because in the joint of the present invention, since the tube is pulled through the oblong-hollow portion of the extrusion, the ends of the tube cannot be round. In the present invention a new manifold structure is attached to the tube ends by a crimping, bonding and clamping process. The initiation manifold of the present invention also has a barrier separating two chambers housing the respective ends of the explosive core, which prevents sympathetic damage to each opposing end of the linear charge.

The separation system is actuated by an electrical signal provided via the manifold to detonate the explosive core, as is known in the art. The explosion causes expansion of the stainless steel tube, which breaks the joint at the two notches to separate it into two parts.

#### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of an extruded frangible joint of the present invention;

FIG. 2 is a section taken along the line 2-2 in FIG. 1 showing in cross section the hollow-form extrusion, stainless steel tube, rubber sheath and explosive core;

FIG. 3 is a cross section similar to FIG. 2, but of a prior art explosive separation system disclosed in U.S. Patent No. 3,698,281;

FIG. 4 is an exploded view of the manifold of the present invention and its attachment to the extruded frangible joint; and

FIG. 5 is a partial cross section of the manifold area of the extruded frangible joint.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIGS. 1 and 2, an extrusion 10 is formed by extruding 6061 aluminum or other suitable material through a suitably shaped die (not shown) and heat treating it to temper it to the T6 condition. The die contains a centerpiece (not shown) having an oblong-shaped cross section. The centerpiece is cantilevered in order to create an oblong-shaped, hollow center portion 12 in the extrusion 10. The extrusion 10 also comprises two flanges 14 and 16 having holes 42 to provide means for attaching the extrusion 10 to the respective structures to be joined -- e.g., two stages of a spacecraft. Extrusion 10 is the structural load carrying component of the frangible joint separation system 8 (as shown in FIG. 1). Two parallel separation grooves or notches 18 and 20, one on either side of the hollow portion 12, provide breakpoints 22 and 24, respectively, of reduced thickness on either side of hollow portion 12. These break-points 22 and 24 are the locations along which separation occurs after detonation of explosive core 30.

After the extrusion 10 has been formed, an elongated tube 26 is inserted into the hollow center portion 12. In the preferred embodiment, tube 26 is 304L (annealed condition) stainless steel and has an outside diameter of 0.625 inch and a wall thickness of 0.049 inch. The purpose of tube 26 is to contain the byproducts of the explosion after detonation of explosive core 30. In applications where contamination is not an issue, however, tube 26 can be omitted. After the tube 26 is inserted into

hollow portion 12, the extrusion 10 is rolled into its desired shape -- e.g., an open ring as shown in FIG. 1. To accommodate the manifold 40, after being rolled the tube 26 and extrusion 10 are trimmed back by using, for example, a mill or handsaw and file.

The explosive core 30 comprises, for example, a Mild Detonating Fuse (MDF) consisting of hexanitrostilbene (HNS) inside an aluminum sheath which is drawn down to a nominal 23.25 grains/foot. The explosive core 30 is inserted into a sleeve 28 of extruded silicone rubber or other suitable material, which holds the explosive core 30 centered in the tube 26. A nominal space is provided between sleeve 28 and tube 26 to allow for manufacturing tolerances. The explosive core 30 and the rubber sleeve 28 are then pulled through the tube 26 and trimmed to the appropriate length, if necessary.

The frangible joint 8, comprising extrusion 10, sleeve 28, explosive core 30 and manifold 40, is now substantially as portrayed in FIG. 1. The final step required to complete the joint 8 is to attach the initiation manifold 40.

Prior art separation joints use tubes with round ends to attach to the manifold as noted above. Because tube 26 in the present invention must be pulled through the length of extrusion 10, the ends of tube 26 are oblong rather than round. Therefore, the present invention also comprises a new manifold 40 and method for attaching it to the end of tube 26. With reference to FIGS. 4 and 5, the initiation manifold comprises a machined stainless steel body 70 having a pair of threaded ports 71 for interfacing initiating Flexible Confined Detonating Cords (FCDCs) 72A and 72B, respectively, with each end of the HNS/aluminum MDF, i.e., explosive core 30. Alternatively, only one port 71 could be used to interface one FCDC with only one end of explosive core 30.

Two plug members 74 and 75, each having at least one crimping notch 76A and 76B (two in the preferred embodiment) in the side, extend outwardly in opposite directions from body 70. Plug members 74 and 75 have a cross section and are dimensioned so as to fit snugly inside the ends of tube 26. Manifold 40 includes co-axial bores 78 and 79 extending along the axis of plug members 74 and 75, respectively, toward the center of manifold 40. The depth of each bore 78 and 79 is such that the two bores do not meet, leaving a barrier 90 of material between the ends of bores 78 and 79. The diameter of bores 78 and 79 is selected to permit the ends of explosive core 30 to be inserted therein. Retaining sleeves 86 and 87 are inserted over the respective ends of tube 26, and serve to reinforce tube 26 against rupture in the area where it protrudes out of extrusion 10. The length of

sleeve 28 is shorter than tube 26 such that there is a gap between each end of sleeve 28 and the corresponding end of tube 26 to permit plug members 74 and 75 to be inserted therein. The respective ends of explosive core 30 then are inserted into bores 78 and 79, respectively, as the respective ends of tube 26 are inserted over plug members 74 and 75, past crimping notches 76A and 76B. Tube 26 is secured to plug members 74 and 75 by crimping tube 26 near each end into crimping notches 76A and 76B. The crimped portions of tube 26 are retained in crimping notches 76A of plug member 74 by a clamp comprised of inboard member 80 and outboard member 81, which are held in position over the end of tube 26 and plug member 74 by fasteners 84 or other suitable means. One end of tube 26 is thereby secured to plug 74 of manifold 40. Similarly, crimped portions near the other end of tube 26 are retained in crimping notches 76B by a clamp comprised of inboard member 82 and outboard member 83, which are held in position by fasteners 84. Thus, the other end of tube 26 is secure to plug 75 of manifold 40. The foregoing arrangement also serves to seal the explosive core 30 within tube 26 and manifold 40. In the preferred embodiment, a suitable adhesive is used to bond the end of tube 26 to plugs 74 and 75 and to strengthen the attachment and provide a better seal. The initiation manifold 40 maintains the proper gap 88A and 88B between loaded receptor cups 91A and 91B at either end of explosive core 30 and the FCDC end tips 89A and 89B, respectively. Loaded receptor cups 91A and 91B are detonated by FCDC 72A and 72B, respectively, which in turn initiate detonation of the respective ends of explosive core 30. Loaded receptor cups 91A and 91B contain charge that serves to enhance detonation transfer from FCDCs 72A and 72B to the respective ends of explosive core 30.

In the preferred embodiment, the manifold 40 is designed to side-initiate the linear charge of explosive core 30 from either FCDC 72A or 72B in separate chambers comprised of bores 78 and 79 isolated from each other by a barrier 90. The separate chambers eliminate sympathetic damage to either end of explosive core 30 that might be caused by the detonation of the other end where the detonation of one end occurs slightly earlier than detonation of the other end.

The joint is attached to the two sections of spacecraft (not shown) to be joined using a plurality of fasteners (not shown) in holes 42. Manifold 40 is attached to one of the structures to be separated, for example, by fasteners (not shown) in holes 41, and it stays attached to that structure after the structures are separated. Upon detonation of the explosive core 30, the stainless steel tube 26

is forced outwardly so as to have a near circular cross section. The deformation of the tube 26 performs work on the interior of the extrusion 10 in the hollow portion 12. This causes cracking and then separation at the weaker breakpoints 22 and 24 in the extrusion 10, which are located beneath separation notches 18 and 20, respectively. The tube 26 in combination with manifold 40, also serves to contain the byproducts of the explosion. Thus, a reliable, clean operating and low cost separation joint and a process for manufacturing it through an extrusion and rolling process have been demonstrated.

Whereas the present invention has been described with respect to specific embodiments thereof, it will be understood that various changes and modifications will be suggested to one skilled in the art and it is intended that the invention encompass such changes and modifications as fall within the scope of the appended claims.

#### Claims

1. An explosive separation system for joining together first and second structures and for explosively separating them, comprising:  
an extruded connecting member having a first flange portion attached to the first structure and a second flange portion attached to the second structure, a hollow portion positioned between said first and second flange portions, and a pair of parallel grooves, one on each side of said hollow portion, said grooves demarcating said first and second flange portions and reducing the thickness of said connecting member on each side of said hollow portion; and  
explosive means for explosively separating said first flange portion from said second flange portion.
2. The explosive separation system of claim 1 wherein said first and second flange portions and said hollow portion comprise a single piece of material.
3. The explosive separation system of claim 1 wherein the cross section of said connecting member is wider in an area adjacent said hollow portion than in the area of said first and second flange portions.
4. The explosive separation system of claim 1 wherein said connecting member has a cross sectional shape of two opposing clevises joined at their open ends.

5. The explosive separation system of claim 1 wherein each said groove is equidistant from the distal end of each of said first and second flange portions.
6. The explosive separation system of claim 1 wherein said hollow portion is elongated in a direction perpendicular to a plane defined by said grooves.
7. The explosive separation system of claim 1 wherein said explosive means further comprises an explosive core within said hollow portion of said connecting member and means for causing said explosive core to explode.
8. The explosive separation system of claim 7 wherein said explosive means further comprises an elastomeric sleeve positioned between said explosive core and the inside surface of said hollow portion.
9. The explosive separation system of claim 8 wherein said explosive means further comprises a metal tube within said hollow portion and wherein said sleeve and said explosive core are positioned within said tube.
10. The explosive separation system of claim 9 wherein said connecting member is rolled to form a portion of a ring.
11. The explosive separation system of claim 10 wherein said explosive means further comprises a manifold and wherein said portion of a ring has two ends, each said end being attached to said manifold, said manifold comprising:
  - a body having first and second plug members, one on each end of said body, each said plug member being positioned and dimensioned to fit within an end of said tube and having a bore therein positioned and dimensioned to receive an end of said explosive core, and each said plug member having at least one notch, wherein a crimped portion of said tube end protrudes into said notch.
12. The explosive separation system of claim 11 further comprising first and second clamp means for maintaining the respective ends of said tube in a fixed position with respect to said first and second plug members.
13. The explosive separation system of claim 11 further comprising first and second retaining sleeves for reinforcing the ends of said tube against rupture.
14. The explosive separation system of claim 11 wherein said explosive means further comprises first and second detonating cord means for detonating respectively the ends of said explosive core, and wherein said body has a third bore intersecting said first bore and a fourth bore intersecting said second bore, said third and fourth bores being dimensioned to receive, respectively, said first and second detonating cord means.
15. The explosive separation system of claim 14 wherein said explosive core further comprises a first loaded receptor cup on one end thereof and a second loaded receptor cup on the other end thereof, wherein said first and second detonating cord means further comprise, respectively, first and second end tips on the end thereof located within said third and fourth bores, respectively, and wherein there is a gap in each of said third and fourth bores, between said first and second end tips and said first and second detonating cords, respectively.
16. The explosive separation system of claim 11 wherein said first and second bores do not intersect, thereby defining a barrier between the ends of said explosive core.
17. An explosive separation system comprising:
  - an integral ring portion, said ring portion having inner and outer peripheral sides defining an enclosed annular cavity, said peripheral sides each being substantially circumscribed by a groove defining an upper flange and a lower flange;
  - explosive means for explosively separating said upper flange from said lower flange, said explosive means further comprising an explosive core extending through said annular cavity; and
  - manifold means for connecting to each end of said ring portion and for initiating detonation of at least one end of said explosive core.
18. A method for making a frangible joint comprising the steps of:
  - extruding a connecting member having a hollow portion and two parallel, linear grooves;
  - inserting a stainless steel tube the length of the hollow portion of the connecting member;
  - forming the connecting member into a final shape;
  - placing an explosive core in an elastomeric sleeve;
  - pulling the explosive core and elastomeric

sleeve through the length of the connecting member via the hollow portion; and  
attaching an initiation manifold to seal the hollow portion.

19. A method in accordance with claim 18 wherein said final shape is a portion of a ring.

20. A method for making an explosive separation system comprising the steps of:

extruding a connecting member having a hollow portion and two parallel, linear grooves adjacent thereto;

forming the connecting member into a final shape;

placing an explosive core in an elastomeric sleeve;

pulling the explosive core and elastomeric sleeve through the length of the connecting member via the hollow portion; and

attaching an initiation manifold to seal the hollow portion and close the joint.

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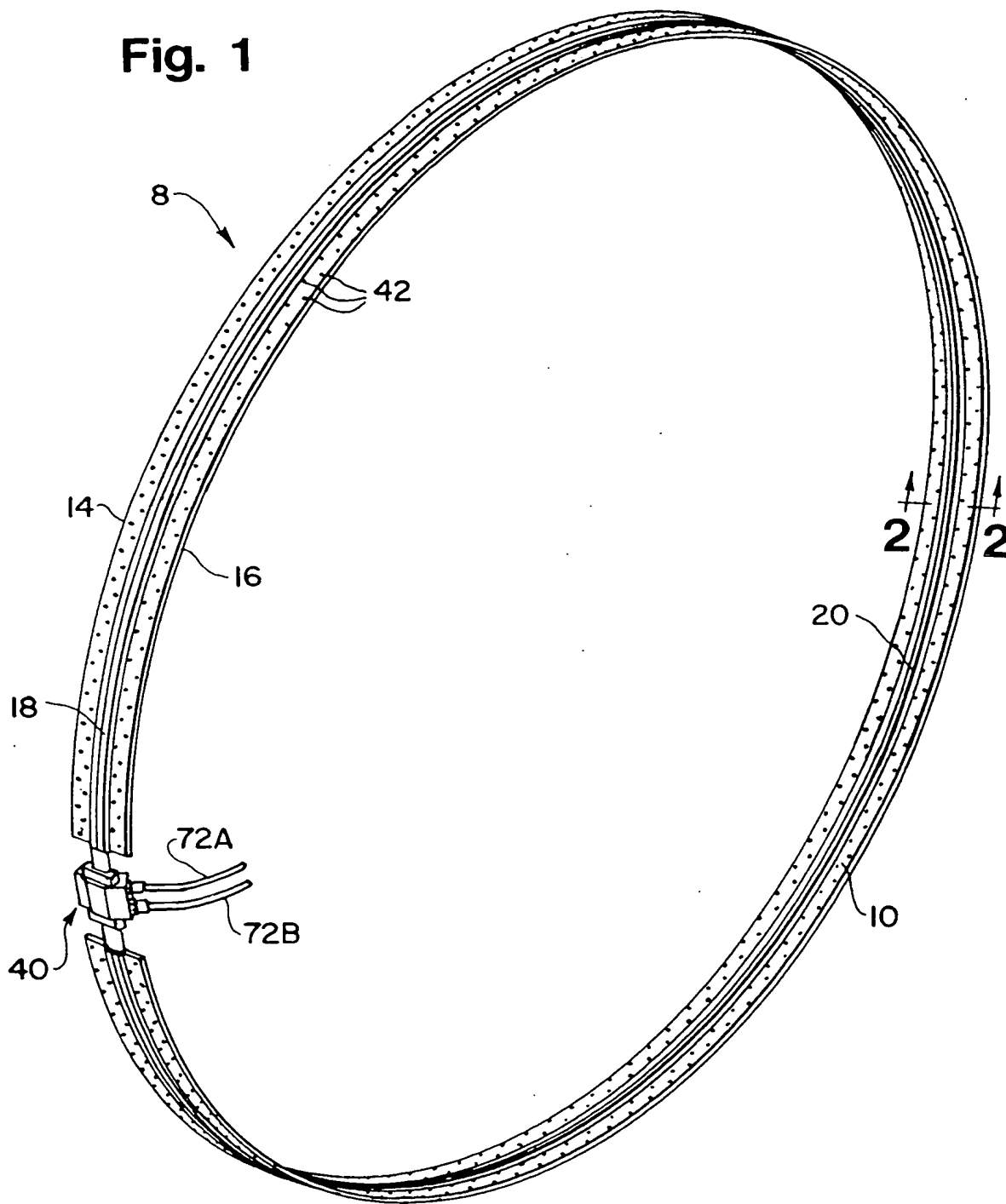
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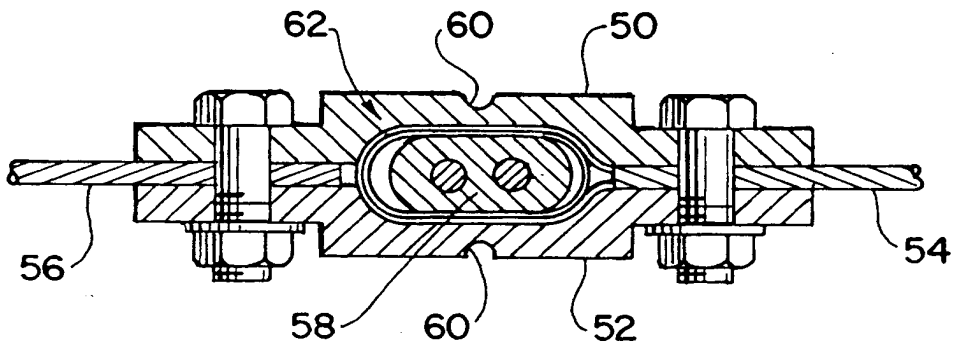
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**Fig. 1**



**Fig. 3 PRIOR ART**



**Fig. 2**

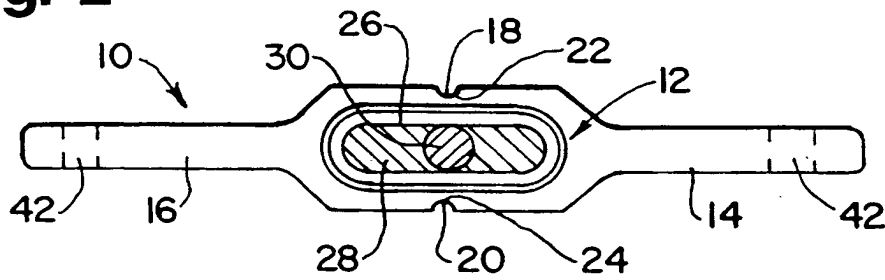


Fig. 4

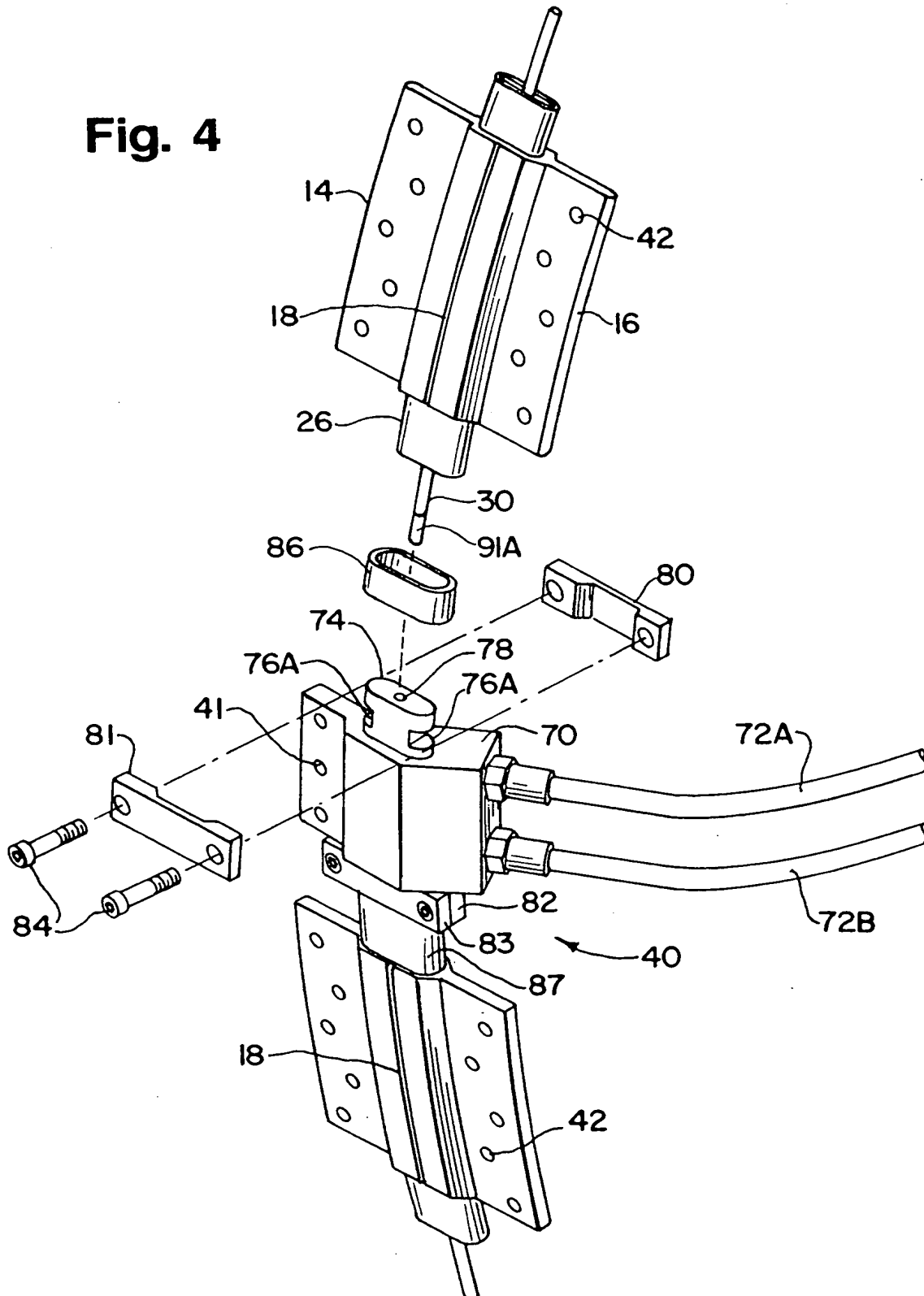
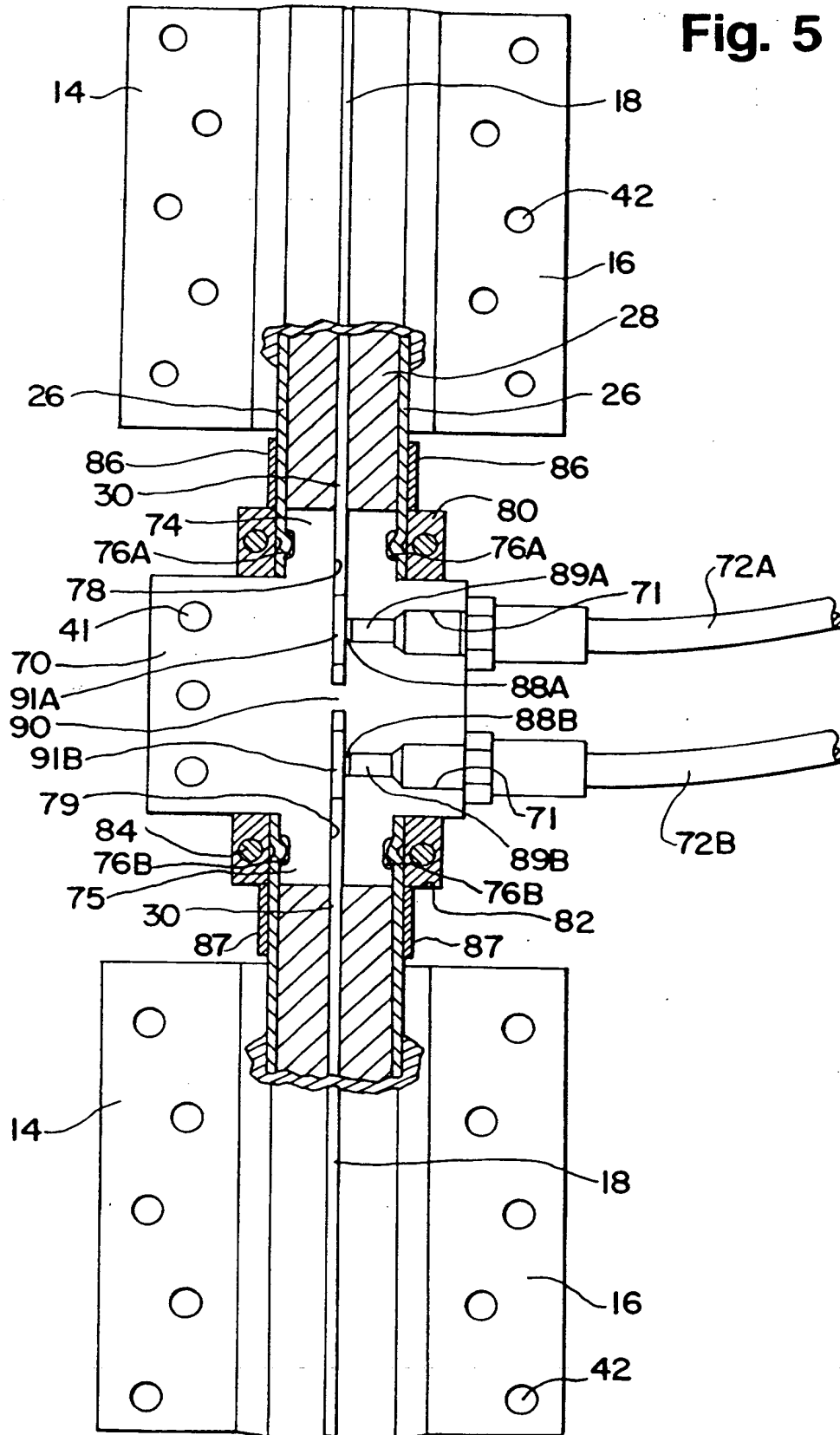


Fig. 5



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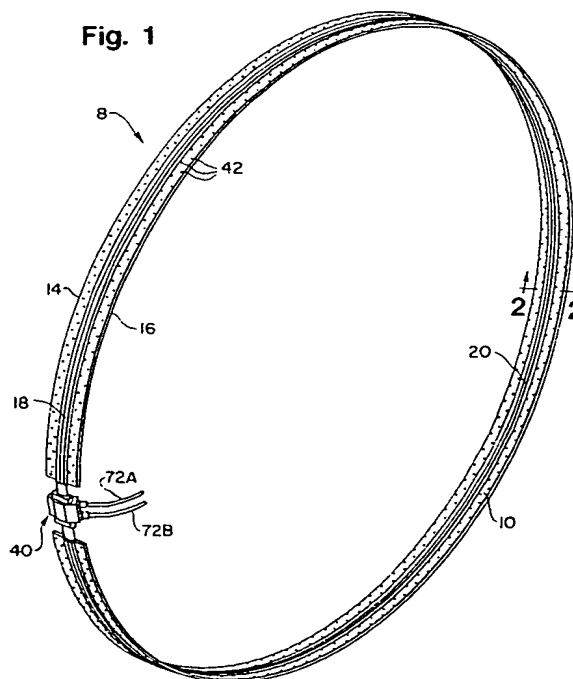
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**13.07.94 Bulletin 94/28**(71) Applicant: **ORBITAL SCIENCES  
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**Alois-Steinecker-Strasse 22**  
**D-85354 Freising (DE)**(54) **Frangible annular joint for connecting and disconnecting two elements.**

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**Fig. 1****EP 0 596 400 A3**



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# EUROPEAN SEARCH REPORT

Application Number  
EP 93 11 7444

## DOCUMENTS CONSIDERED TO BE RELEVANT

DOCUMENTS CONSIDERED TO BE RELEVANT			CLASSIFICATION OF THE APPLICATION (Int.Cl.5)
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	
D,Y	US-A-3 698 281 (O. BRANDT)  * column 2, line 58 - column 3, line 37; figures 3A,3B *	1-10, 18-20	F42B15/38
X	----	17	
Y	US-A-5 010 823 (P. MORRISON)  * column 2, line 4-41; figures 1-5 *	1-10, 18-20	
X	EP-A-0 472 453 (AEROSPATIALE SOCIETE NATIONALE INDUSTRIELLE) * column 5, line 34 - column 7, line 34; figures 2,4,5 *	17	
A	FR-E-82 522 (ETAT FRANÇAIS) * the whole document *	17	
A	EP-A-0 246 958 (AEROSPATIALE SOCIETE NATIONALE INDUSTRIELLE) -----		
			TECHNICAL FIELDS SEARCHED (Int.Cl.5)
			F42B B26F B64G
The present search report has been drawn up for all claims			
Place of search	Date of completion of the search	Examiner	
THE HAGUE	2 May 1994	Van der Plas, J	
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